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## PATENT ABSTRACTS OF JAPAN

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## (54) RARE-EARTH BONDING MAGNET

## (57)Abstract:

PROBLEM TO BE SOLVED: To provide a rare-earth bonding magnet, which is economical and has high performances.

SOLUTION: This rare-earth bonding magnet is the rare-earth-based magnetic material containing Nb<sub>2</sub>Fe<sub>14</sub>B-type crystal. This material is constituted of the magnetic powder, which is the crushed powder of the quickly cooled thin belt having a rare-earth-element content of 8-11at.% and iH<sub>c</sub> of 7 kOe or more and has the average particle diameter of 110μm or more, and the magnetic powder having the following properties. This magnetic powder is the crushed powder of replaced-spring-magnet thin belt with an average particle size of 50μm or less, which is constituted of soft magnetic phase and hard magnetic phase, which have a rare-earth-element content of 8wt.% or less, an iH<sub>c</sub> of 3.5-6.0 kOe, a Br of 10kG or more and a crystal-particle diameter controlled at 10-100μm, and amorphous phase having 10 area % or less and bonding resin. Thus, the rare-earth-bond magnet having the magnetic characteristics of the Br (remnant magnetic filed density) of 8kG or more, an iH<sub>c</sub> (coercive force) of 5 kOe or more and an energy product (BH) max of 11MGOe or more is obtained.

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CLAIMS

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[Claim(s)]

[Claim 1] The following magnetic powder (A), mixed magnetic powder with (B), and the resin for association are made into a main constituent, a residual magnetic flux density  $B_r$  is 8 or more kGs, and coercive force  $iH_c$  is 5kOe(s). Rare earth bond magnet characterized by energy product (BH) max having the magnetic properties of 11 or more MGOes above.

(A) It is a rare earth system magnet ingredient including a Nd<sub>2</sub>Fe<sub>14</sub>B mold crystal. The content of rare earth elements is 8-11at.%, and coercive force  $iH_c$  is 7kOe(s). Coercive force  $iH_c$  below 8at(s).% by the pulverized powder of the above quenching thin band by 3.5-6.0kOe [ mean particle diameter ] [ the content of magnetic powder 100 micrometers or more and (B) rare earth elements ] A residual magnetic flux density  $B_r$  is the pulverized powder of the exchange spring magnet thin band which consists of a soft magnetism phase controlled by 10-100nm, a hard magnetism phase, and an amorphous phase below 10 area %, and the diameter of crystal grain of 10 or more kGs is magnetic powder with a mean particle diameter of 50 micrometers or less.

[Claim 2] The rare earth bond magnet according to claim 1 obtained by compression molding.

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DETAILED DESCRIPTION

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[Detailed Description of the Invention]

[0001]

[Field of the Invention] For this invention, about a highly efficient and economical rare earth bond magnet, in more detail, in spite of being a rare-earth-elements low content, a residual magnetic flux density Br is 8 or more kGs, and coercive force iHc is 5kOe(s). It is above and is related with the rare earth system bond magnet with which energy product (BH) max has 11 or more MGOes and the high engine performance.

[0002]

[Description of the Prior Art] Conventionally, the rare earth system bond magnet is used abundantly in the form of the magnet for motors as an electronic electrical part centering on Nd system isotropy compression-molding magnet. It is used for the pager, cellular one, etc. which are the hard disk drive (HDD) which is especially a computer loading device, CD-ROM, the printer which is this peripheral device, a scanner, and pocket communication equipment in large quantities.

[0003] However, the demand of a more powerful and economical magnet is increasing with the formation of small lightweight of these devices especially in recent years. Although a rare earth system sintered magnet (Nd system, Sm system) and Sm system anisotropy bond magnet are powerful magnets which have a high energy product rather than Nd system isotropy bond magnet, since they are inferior to economical efficiency, they are hardly used for the motor application of the above-mentioned device.

[0004] Now as raw material magnetic powder of Nd system isotropy bond magnet, only the MQP (trade name) magnetic powder (product made from MQI) that the U.S. GM company developed is supplied on a scale of industry, and especially MQP-B grade is actively used also among this MQP magnetic powder. the general presentation of this MQP-B magnetic powder -- Nd<sub>12</sub>Fe<sub>76.5</sub>Co<sub>5.5</sub> B6 near the stoichiometric composition of the Nd<sub>2</sub>Fe<sub>14</sub>B mold crystal structure it is -- magnetic properties The magnetic properties of the compression-molding bond magnet (MQI-B10) which are Br=8.2kG, iHc=9.0kOe, and (BH) max=12.0MGOe in nominal rating, and used this magnetic powder They are Br=6.9kG, iHc=9.0kOe, and (BH) max=10.0MGOe (it is based on a MQI catalog.). .

[0005] Moreover, in JP,8-124730,A, they are Nd<sub>12</sub>\*\*0.5at.% near Nd<sub>2</sub>Fe<sub>14</sub>B stoichiometric composition, and coercive force iHc=10kOe. Coercive force 4-10kOe which mixed quenching fine particles and the exchange spring magnet fine particles which consist of a software magnetism phase by which crystal grain was controlled by 20-50nm, and a hard magnetism phase, and hardened this by resin The low coercive force rare earth resin magnet is indicated. However, the purpose of the above-mentioned

invention is to offer the rare earth resin magnet excellent in multi-electrode magnetization nature as indicated by the epitome, and, for this reason, it has become a chief aim to reduce coercive force by powder mixing. Therefore, the magnetic properties indicated by the example do not exceed the magnetic properties of above-mentioned MQI-B10, either. Although the demand of the economical magnet which is high magnetism increasingly in recent years is increasing like the above, the actual condition is that the magnet it may fully be satisfied with both sides of the engine performance and economical efficiency of the magnet is not yet proposed.

[0006]

[Problem(s) to be Solved by the Invention] This invention makes it a technical problem to offer economically the bond magnet which has Br higher than present MQI-B10, has iHc of extent which does not spoil square shape nature in view of the above-mentioned actual condition, and has (BH) max higher than MQI-B10 as a result.

[0007]

[Means for Solving the Problem] Generally the theoretical energy product of a permanent magnet is  $(BH)_{max} = 0.25 \times Br^2$ . It is expressed. Therefore, in order to obtain the bond magnet which has a high energy product rather than MQI-B10, it becomes indispensable to use the magnetic powder which has higher Br. In this case, iHc can use the magnetic powder which has iHc lower than the above-mentioned MQP-B magnetic powder as long as this condition is satisfied, since square shape nature is not spoiled, therefore an energy product is not made to fall if  $iHc > 0.5 \times Br$  is satisfied theoretically.

[0008] As one of such the magnetic powder, there is an exchange spring magnet recent years especially with prosperous researches and developments. An exchange spring magnet has high possibility of a magnetic spring phenomenon being shown, and the description being having the amount of low rare earth elements, and the high residual magnetic flux density Br, and becoming the magnet excellent in cost performance by the exchange interaction of iron or an iron compound, and a Nd<sub>2</sub>Fe<sub>14</sub>B mold tetragonal compound.

[0009] That is, since the rare earth-iron-boron system exchange spring magnet alloy of under 10 atom % can reduce the amount of rare earth with it compared with the rare earth-iron-boron system magnet alloy of 11 - 15 atom % with the amounts of rare earth near stoichiometric composition, such as Nd, like "MQP" (trade name) of marketing which for example, the U.S. GM company developed, the amounts of rare earth elements, such as Nd, have the description of being economical. [ high and BOTENSHARU on magnetic properties, and ] [ expensive ]

[0010] There is a system in which these amounts of rare earth elements, such as Nd, contain the system which contains above alphaFe and bccFe in the rare earth-iron-boron system exchange spring magnet alloy of under 10 atom % as a soft magnetism phase, and Fe<sub>3</sub>B and Fe<sub>2</sub>B. although the residual magnetic flux density Br of the former is generally as high as 10-13kG according to the scientific reference etc. -- coercive force iHc -- at most -- 3.5kOe(s) Are as low as the following. The latter Generally coercive force iHc is 3.5-7.7kOe. Although the residual magnetic flux density Br was high compared with above-mentioned MQP-B (Br=8.2) since a residual magnetic flux density Br was below 10kG extent, although it is comparatively high, compared with the former alphaFe subject system, it was low.

[0011] So, in this invention, (B) was mixed with two kinds of magnetic powder (A), and it hit on an idea of improving the magnetic properties of a bond magnet using this. It has higher Br as one magnetic powder, and alphaFe-NdFeB system exchange spring magnet powder (B) with which a residual amorphous phase

exists below 10 area % is chosen. Namely, as another magnetic powder iHc is 7kOe(s), although a rare earth content is rich in economical efficiency few from the above-mentioned MQP-B magnetic powder and Br is low as compared with magnetic powder (B). As a result of choosing the above and known high magnetic powder (A) and experimenting in many things, as magnetic properties of a bond magnet  $Br \geq 8\text{kG}$ ,  $iHc \geq 5\text{kOe}$ , and  $(BH)_{\max} \geq 11\text{MGOe}$  are realized. That is, it came to complete a header and this invention for the ability of iHc to offer the magnet which was excellent in Br and  $(BH)_{\max}$  although it was low, and was excellent in economical efficiency as compared with above-mentioned bond magnet MQI-B10.

[0012] Namely, this invention makes a main constituent the following magnetic powder (A), mixed magnetic powder with (B), and the resin for association, a residual magnetic flux density Br is 8 or more kGs, and coercive force iHc is 5kOe(s). The rare earth bond magnet characterized by energy product  $(BH)_{\max}$  having the magnetic properties of 11 or more MGOes is made into the contents above. (A) It is a rare earth system magnet ingredient including a Nd<sub>2</sub>Fe<sub>14</sub>B mold crystal. The content of rare earth elements is 8-11at.%, and coercive force iHc is 7kOe(s). Coercive force iHc below 8at(s).% by the pulverized powder of the above quenching thin band by 3.5-6.0kOe [ mean particle diameter ] [ the content of magnetic powder 100 micrometers or more and (B) rare earth elements ] A residual magnetic flux density Br is the pulverized powder of the exchange spring magnet thin band which consists of a soft magnetism phase controlled by 10-100nm, a hard magnetism phase, and an amorphous phase below 10 area %, and the diameter of crystal grain of 10 or more kGs is magnetic powder with a mean particle diameter of 50 micrometers or less.

[0013] As magnetic powder (B) used for this invention, it is previously developed by this invention persons and the thing of patent pending (Japanese Patent Application No. 8-226021) is suitable. Specifically formula  $R_xFe_{100-x-y-z-w}$  Coy MZ Bw [ -- however, R A kind of the rare earth elements chosen from Nd, Pr, Dy, Tb, and Ce or two sorts or more, and M A kind of the element chosen from Ti, V, Cr, Zr, Nb, Mo, Hf, Ta, W, Mn, Cu, Ga, Zn, In, Sn, Bi, Ag, and Si or two sorts or more, x, and y, z and w respectively -- an atomic ratio --  $5 \leq x \leq 10$ ,  $1.0 \leq y \leq 9.0$ ,  $0.1 \leq z \leq 5$ , and  $2 \leq w \leq 7$  -- and It has the presentation expressed with  $9 \leq (x+w)$  and  $5 \leq (y+z)$ .  $\alpha\text{Fe}$ ,  $\text{bccFe}$  and these, the soft magnetism crystal phase containing the solid solution with Above M, and Nd<sub>2</sub>Fe<sub>14</sub>B As the hard magnetism crystal phase which consists of a mold tetragonal-system crystal, respectively It has the alloy organization which deposits in a soft magnetism amorphous phase, and said soft magnetism amorphous phase is below 10 area % to all alloy organizations. The remainder is said soft magnetism crystal phase and said hard magnetism crystal phase, and said soft magnetism crystal phase is the rare earth-iron-boron system magnet alloy characterized by being at least 50 area % and the remainder being said hard magnetism crystal phase to all the crystalline structures. the magnetic powder which is used for this invention according to the above-mentioned technique (B), i.e., the content of rare earth elements, -- below 8at(s).% and coercive force iHc -- 3.5-6.0kOe Magnetic powder with a mean particle diameter of 50 micrometers or less can be easily prepared by the pulverized powder of the exchange spring magnet thin band with which a residual magnetic flux density Br consists of a soft magnetism phase by which the diameter of crystal grain of 10 or more kGs was controlled by 10-100nm, a hard magnetism phase, and an amorphous phase below 10 area %.

[0014] Although high Br of 10 or more kGs which are the requirements for the magnetic powder (B) of this invention will become difficult to get and especially a minimum will not be restricted on the other hand

since the content of iron-group falls relatively if the content of the rare earth elements of magnetic powder (B) exceeds 8at(s).%, they are 3.5kOe(s) about iHc. In order to maintain above, as for rare-earth-elements content, it is desirable that it is more than 5at(s).%. Moreover, coercive force iHc is 3.5kOe(s). In the following, the degree of the-like-proportionally fall of iHc becomes large, and cannot attain (BH) max $\geq$ 11MGOe as a result rather than the rise effectiveness of Br by mixed magnetic powder, but, on the other hand, it is 6.0kOe. If it exceeds, generally Br will fall more often relatively and high Br of 10 or more kGs which are the requirements for magnetic powder (B) will become difficult to get. They are 5.5kOe(s) preferably. Furthermore, although the residual magnetic flux density Br of Br is too small in less than 10 kGs, the bond magnet of the high performance made into the purpose of this invention is not obtained as a result and especially an upper limit is not restricted on the other hand, they are 3.5kOe(s) about iHc. If balance called the above is taken into consideration, usually it will be set to 15 or less kGs. The diameter of crystal grain of magnetic powder (B) of  $\alpha$ -Fe or an iron compound which the alloy organization has nano composite structure, and the magnitude of a Nd<sub>2</sub>Fe<sub>14</sub>B mold crystal which is a hard magnetism phase is 10-100nm, and is a soft magnetism phase is also 10-100nm. Generally in less than 10nm, the superparamagnetism-behavior of these diameters of crystal grain increases, they cause the fall of Br, and on the other hand, if 100nm is exceeded, the fall of coercive force will become remarkable. Moreover, since the amorphous phase of the remainder which occupies 10 - 1 area % preferably encloses these crystal phases below 10 area %, an alloy is ground, for example, magnetic properties are not degraded remarkably as fine particles with a mean particle diameter of 50 micrometers or less. If the amorphous phase of the remainder exceeds 10 area %, the magnetic exchange interaction of a soft magnetism crystal phase and a hard magnetism crystal phase will be weakened, and point of inflection will be brought about on a fall and demagnetization curve of coercive force. Moreover, when it comes to under 1 area %, there is an inclination which becomes easy to receive distortion and causes the sharp fall of coercive force iHc at the time of grinding used as magnetic powder. Furthermore, iHc is 3.5kOe(s), although high Br of 10 or more kGs will become difficult to get and especially an upper limit will not be restricted on the other hand, if a soft magnetism crystal phase becomes under 50 area % to all the crystalline structures. In order to become the above, since a hard magnetism crystal phase is required for more than 10 area %, if a total is carried out, 80 area % will become a general upper limit.

[0015] The magnetic powder (A) used for this invention 8-11at.% Contains rare earth elements, and iHc is 7kOe(s). It consists of the above known magnet ingredient, and is manufactured mainly by the melt quenching method and heat treatment (when the optimal quenching is given, a heat treatment process may be able to be skipped). About the alloy presentation of magnetic powder (A), it is not necessary to prepare especially other limitation in this invention that what is necessary is just to limit the amount of rare earth elements from a viewpoint of economical efficiency. Especially the presentation by the side of transition metals may contain effective various alloying elements so that it may next illustrate.

[0016] For example, various alloys are indicated by JP,64-703,A, for example, it is Nd<sub>11</sub>Fe<sub>79</sub>Nb<sub>2</sub>Ta<sub>2</sub>B<sub>6</sub>. The magnetic properties of the quenching ribbon of a presentation are indicated to be Br=8.3kG, iHc=14.9kOe, and (BH) max=14.0MGOe (the 1st table; No24). Moreover, in JP,64-7502,A, it is Nd<sub>8</sub>Fe<sub>70</sub>Co<sub>10</sub>Zr<sub>3</sub>Ti one B8. The magnetic properties of an alloy ribbon are indicated to be Br=8.6kG, iHc=11.1kOe, and (BH) max=15.2MGOe (the 2nd table, No5).

[0017] Furthermore, various alloys are indicated by JP,4-47024,B, for example, it is Nd<sub>11</sub>Fe<sub>72</sub>Co<sub>8</sub>V<sub>1.5</sub>B<sub>7.5</sub>. It is indicated that the alloy of a presentation has the magnetic properties of Br=9.7kG,



$iH_c=12.9\text{kOe}$ , and  $(BH)_{\text{max}}=20.1\text{MGOe}$  with a quenching thin band (the 1st table, No4). These alloys can be used as magnetic powder (A) in this invention.

[0018] Here, the reason which limited the rare-earth-elements content of magnetic powder (A) to 8 - 11at.% is that  $iH_c$  can obtain the magnetic powder which excelled [  $\text{max} / (BH)$  ] the larger top in the sufficiently high top also at magnetization nature as indicated by not only the economical reason for lessening the amount of the expensive rare earth elements used but the above-mentioned specification compared with the above-mentioned MQP-B magnetic powder. Furthermore, they are 7kOe(s) about  $iH_c$ . For the reason considered as the above, generally, the coercive force of magnetic powder (B) is 6kOe(s) low. Since extent is an upper limit, it is for securing sufficient coercive force for extent which does not spoil the square shape nature of the demagnetization curve of a bond magnet according to the magnetic powder mixing effectiveness. Especially the upper limits of  $iH_c$  are 17kOe(s) if the magnetization nature of a bond magnet is taken into consideration, although not restricted. The following is desirable.

[0019] Although magnetic powder (A) is generally called mixed phase of a  $\text{Nd}_2\text{Fe}_{14}\text{B}$  mold crystal single phase or this main phase, and a minute amount grain boundary phase, the diameter of crystal grain is several 10nm size. However, since these alloys tend to be influenced of distortion by grinding and coercive force will decline gradually if grinding grain size is lowered, 100-micrometer order is practically made into the limitation of grinding fine-particles particle size.

[0020]

[Function] This invention adjusts magnetic powder (B) to the mean particle diameter of 50 micrometers or less, and adjusts magnetic powder (A) to the mean particle diameter of 100 micrometers or more. (A) The place which produced the resin bond magnet with compression molding using the mixed magnetic powder which set up the mixed ratio of pair (B) between 1 to 9 and 9 to 1 by the weight ratio, The vena contracta does not have a magnetic demagnetization curve mostly, namely, the knowledge of becoming a smooth curve without the point of inflection which was conspicuous on the demagnetization curve is carried out, and this smooth demagnetization curve realizes the bond magnet excellent in the magnetic energy product.

[0021] It is [  $\text{Sm}_2\text{Co}_{17}$  system magnetic powder (particle-size size) and ]  $\text{Sm}_2\text{Fe}_{17}\text{N}_3$  by Kitazawa and others to the Magnetics Society of Japan and 20,221-224 (1996) as an example which mixes and presses the magnetic powder with which particle size distribution differs, and acquires a good property for an anisotropy bond magnet. Mixed combination with system magnetic powder (particle-size smallness) is reported. According to this report, the smooth demagnetization curve which does not have the vena contracta mostly over the mixed ratio whole region has been obtained, and what the static magnetism magnetic interaction committed between magnetic powder as a cause is considered. Moreover, in order that the rate of a volume ratio of all the magnetic powder that originates in the difference of particle size distribution by the way, and is occupied in a bond magnet of a certain mixing ratio may increase, it is also reported that the good high magnetic properties of  $\text{Br}(BH)_{\text{max}}$  are realized.

[0022] Therefore, also in the isotropic bond magnet using Nd system alloy of this invention, it is imagined as that from which the magnetic interaction between magnetic powder worked [ experimental result ], and the smooth demagnetization curve was obtained. Furthermore, although it was dependent on the particle size of two kinds of magnetic powder, as shown in the following examples, by the way, the rate of a volume ratio of all magnetic powder (filling factor of magnetic powder) has the maximal value, and the thing of a certain mixed ratio which the magnetic properties of an isotropic bond magnet especially  $\text{Br}$ ,

and (BH) max improve rather than the value of an arithmetic average was also checked.

[0023]

[Embodiment of the Invention] The powder of the exchange spring magnet in which this invention persons did patent application previously is suitable for magnetic powder (B). Generally After producing the alloy of the purpose presentation with a solution process and changing into an amorphous condition with a melt quenching method etc., by heat-treating It is the powder which a hard magnetism crystal phase and a soft magnetism crystal phase are deposited in moderate magnitude from a soft magnetism amorphous phase, changes into the condition that these three phases lived together, as the result, grinds this, and is obtained. In addition, the sequence of heat treatment and grinding may get mixed up.

[0024] For magnetic powder (A), although it is good with the powder of a known quenching thin band alloy, the content of rare earth elements is 8-11at.% in the aforementioned reason, and coercive force  $iH_c$  is 7kOe(s). It is necessary to have the above conditions. Generally, the alloy of the purpose presentation is produced with a solution process, and after this powder also changes into an amorphous condition with a melt quenching method etc., it is obtained by heat-treating and grinding. Also in this case, the sequence of heat treatment and grinding may get mixed up. However, generally as for this alloy, the limit on the presentation of the range of rare earth content etc. consists of a mixed phase of a single phase or the main phase, and a minute amount grain boundary phase with the main factor, and the configuration phase with fundamental soft magnetism crystal phase or soft magnetism amorphous phase has not become like the above-mentioned magnetic powder (B). However, it cannot be overemphasized that, as for existence of a minute amount, the two latter phases are allowed very much as a grain boundary phase or an impurity phase.

[0025] Mixed magnetic powder (A+B) needs to raise the pack density of the magnetic powder in a bond magnet by setting up more greatly than the particle size of magnetic powder (B) the fine-particles particle size of magnetic powder (A), and mixing. If an average value sets the fine-particles particle size of magnetic powder (A) as 100 micrometers or more, a high property bond magnet will be obtained. It is 100-200 micrometers more suitably. The mean particle diameter of magnetic powder (B) is set as 50 micrometers or less. It is 20-50 micrometers more suitably. Grinding and mixing of these magnetic powder can be performed by general technique. For example, they are grinding by the ball mill or the attritor mill, classification by the vibrating screen, and stirring mixing by the ribbon blender or the planetary blender. Magnetic powder (A) and the mixed ratio of (B) are set up so that highest energy product (BH) max may be obtained. Since the optimal numeric value is changed with the magnetic properties and mean particle diameter which both magnetic powder has, it is necessary to grasp this ratio well by experiment beforehand. Next, the resin for association (binder polymer) etc. can be added before the above-mentioned stirring mixing or to the back, and compounding for considering as the charge of shaping material can be performed.

[0026] As resin for association, when producing a compression-molding magnet, the thermosetting resin of an epoxy system or a phenol system is common, and when producing an injection-molding magnet, the thermoplastics of a polyamide (nylon) system, a polyphenylene sulfide (PPS) system, or a liquid crystal resin system is common. Furthermore, if extrusion molding and calender roll shaping also choose a suitable binder, it can carry out. As for the rare earth bond magnet of this invention, it is desirable to manufacture with compression molding especially in that can demonstrate more efficiently the effectiveness indicated to the aforementioned operation, and high magnetic properties can be acquired.

[0027] Hereafter, a compression-molding magnet is explained to a detail as a subject. the purpose which makes shaping easy or fully pulls out magnetic properties in the compound for compression molding -- the need -- everything but a binder polymer -- the additive of common knowledge, such as a plasticizer, lubricant, and a coupling agent, -- little \*\*\*\*\* -- things are made.

[0028] Compression molding can be performed by the approach of producing the isotropic conventional bond magnet. That is, although it can manufacture using a commercial press-forming machine, since pack density goes up and the direction set up as much as possible more highly industrially brings about a raise in Br of an isotropic bond magnet, as a result (Quantity BH) max-ization, especially the press pressure is advantageous.

[0029] Resin hardening of the magnet by which compression molding was carried out is carried out by the following heat treatment process, and, subsequently, usually, it is magnetized. However, it may be magnetized after a case unites with components besides after resin hardening. In any case, being magnetized by pulse current is common. Generally the magnetic properties of the produced bond magnet are measured by the B-H curve tracer. An irreversible loss ratio required for magnetic stability evaluation etc. is measured with a fluxmeter.

[0030] Next, an example is given and explained about the typical embodiment of this invention. As magnetic powder (A) which is high coercive force magnetic powder, it is Nd<sub>11</sub>Fe<sub>72</sub>Co<sub>8</sub>V<sub>1.5</sub>B<sub>7.5</sub>. After choosing the presentation and producing the quenching thin band, 650 degrees C and heat treatment for 5 minutes were performed and ground, and powder was produced. The magnetic properties of the ribbon before grinding of this alloy were Br=9.7kG, iHc=12.9kOe, and (BH) max=20.1MGOe. On the other hand, it is Nd<sub>7.5</sub>Fe<sub>83</sub>Co<sub>4.5</sub>Nb<sub>1</sub>B<sub>4</sub> as magnetic powder (B) which is the powder of an exchange spring magnet. The alloy of a presentation was chosen. After making this alloy amorphous with a melt quenching method, 740 degrees C and heat treatment for 3 minutes were performed. The diameter of crystal grain was [ about 8 area % and the soft magnetism crystal phase of 10-50nm and a soft magnetism amorphous phase ] about 60 area %s. The magnetic properties of the ribbon before grinding of this alloy were Br=11.9kG, iHc=4.8kOe, and (BH) max=18.8MGOe.

[0031] Magnetic powder (B) was brandished on the fine-particles grain size of 10 micrometers or more, and 70 micrometers or less (mean particle diameter of 50 micrometers), a screen and magnetic powder (A) were brandished on the fine-particles grain size of 100 micrometers or more, and 200 micrometers or less (mean particle diameter of 150 micrometers), and grain refining was carried out. Next, magnetic powder (A) and magnetic powder (B) were often mixed, and it set up so that the weight ratio of the magnetic powder (B) occupied in the whole amount of magnetic powder might become 0, 10, 20, 30, 40, 50, 60, 70, and 80 or 90, 100%. Next, about 2 % of the weight of epoxy resins is used as a binder, and it is 7 t/cm<sup>2</sup>. The pressure was put, the compression-molding bond magnet was produced, and the magnetic properties of a room temperature were measured by BH curve tracer. The filling factor of magnetic powder was computed from the volume and consistency of a bond magnet. In addition, the magnetic properties of the compression-molding bond magnet of (magnetic powder A) independent use [(magnetic powder B):0%] were Br=7.7kG, iHc=12.5kOe, and (BH) max=12.2MGOe. Moreover, the magnetic properties of the compression-molding bond magnet of (magnetic powder B) independent use [(magnetic powder B):100%] were Br=9.2kG, iHc=4.5kOe, and (BH) max=11.1MGOe.

[0032] A demagnetization curve in case the mixed ratio of magnetic powder (A) and magnetic powder (B) is 50% each is shown in drawing 1 . If fine-particles grain size is appropriately adjusted even when the

magnetic powder with which magnetic properties differ is mixed from this drawing 1, it turns out that a comparatively smooth curve without the point of inflection which was conspicuous on the demagnetization curve is obtained, and the magnetic interaction is working between different-species magnetic powder also in this invention. Such a demagnetization curve that does not have point of inflection mostly was obtained in the bond magnet of the mixed ratio of all above.

[0033] next, drawing 2 -- each -- the magnetic properties and the magnetic powder filling factor of a bond magnet which used the magnetic powder of a mixing ratio are shown. Drawing 2 shows that, as for a filling factor, magnetic powder (B) takes the maximal value near 20%. Although a residual magnetic flux density  $B_r$  becomes larger than the average similarly in connection with this, since  $B_r$  of magnetic powder (B) is larger than  $B_r$  of magnetic powder (A), from 50% or more, it goes up little by little. Coercive force  $iH_c$  showed the inclination to follow an average straight line mostly. As a result, magnetic powder (B) shows the fall with about 70 loose%, without maximum energy product  $(BH)_{max}$ 's being influenced by change of  $B_r$ , and falling rapidly also after that, although magnetic powder (B) takes the maximal value near 20%. Therefore,  $B_r$  made into the purpose of this invention is 8 or more kGs, and  $iH_c$  is 5kOe(s). In the case of this embodiment, the mixed ratio of the magnetic powder (B) with which  $(BH)_{max}$  is satisfied of 11 or more MGOes serves as 10 - 90% of range above. Moreover, the highest energy products were 13.0MGOe(s) near 20%.

[0034]

[Example] Next, although an example and the example of a comparison are given and being further explained to a detail, these do not restrict the range of this invention at all.

As magnetic powder (A) which is example 1 quantity coercive force magnetic powder, it is Nd<sub>8.5</sub>Fe<sub>70</sub>Co<sub>10</sub>Zr<sub>3</sub> Ti 0.5B<sub>8</sub>. The presentation alloy was chosen and the quenching thin band was produced. The magnetic properties after heat treatment of this thin band were  $B_r=8.6$ kG,  $iH_c=11.1$ kOe, and  $(BH)_{max}=15.2$ MGOe. As magnetic powder (B) which is the powder of one exchange spring magnet, it is Nd<sub>6</sub>Pr<sub>1</sub> Fe<sub>83.5</sub>Co<sub>4</sub> Ti<sub>1</sub> Ga<sub>0.5</sub> B<sub>4</sub>. The alloy of a presentation was chosen. The magnetic properties after heat treatment of the thin band ribbon of this alloy were  $B_r=11.6$ kG,  $iH_c=4.7$ kOe, and  $(BH)_{max}=18.6$ MGOe. Moreover, the diameter of crystal grain was [ about 9 area % and the soft magnetism crystal phase of 20-60nm and a soft magnetism amorphous phase ] about 65 area %s.

[0035] The fine-particles grain size of magnetic powder (B) was used on 50 micrometers or less (mean particle diameter of 35 micrometers), the fine-particles grain size of a screen and magnetic powder (A) was used on 100 micrometers or more and 250 micrometers or less (mean particle diameter of 175 micrometers), and grain refining was carried out. After that, the bond magnet by mixed magnetic powder was produced like the mode of said operation, and magnetic properties etc. were measured. In addition, the magnetic properties of the compression-molding bond magnet of (magnetic powder A) independent use were  $B_r=6.7$ kG,  $iH_c=10.7$ kOe, and  $(BH)_{max}=9.3$ MGOe. Moreover, the magnetic properties of the compression-molding bond magnet which carried out independent use of the magnetic powder (B) were  $B_r=9.0$ kG,  $iH_c=4.5$ kOe, and  $(BH)_{max}=10.8$ MGOe.

[0036] drawing 3 -- each -- the magnetic properties and the magnetic powder filling factor of a bond magnet which used the magnetic powder of a mixing ratio are shown. Drawing 3 shows that, as for a filling factor, magnetic powder (B) takes the maximal value near 30%. Therefore,  $B_r$  made into the purpose of this invention is 8 or more kGs, and  $iH_c$  is 5kOe(s). In the case of this example, the mixed ratio of the magnetic powder (B) with which  $(BH)_{max}$  is satisfied of 11 or more MGOes serves as 20 - 40% of

range above. Moreover, the highest energy products were 12.0MGOe(s) near 30%.

[0037] As magnetic powder by the side of example 2 quantity coercive force (A), it is Nd<sub>9</sub> Dy<sub>0.5</sub> Fe<sub>70.5</sub> Co<sub>10</sub> Ni<sub>1</sub> Nb<sub>3</sub> B<sub>6</sub>. The presentation was chosen and the quenching thin band was produced. The magnetic properties after heat treatment of this thin band were Br=8.4kG, iHc=12.9kOe, and (BH) max=14.7MGOe. This thin band was ground and a screen and the powder which carried out grain refining were produced for fine-particles grain size to 100 micrometers or more and 300 micrometers or less (mean particle diameter of 200 micrometers). The magnetic properties of the compression-molding bond magnet of use of only magnetic powder (A) were Br=6.5kG, iHc=12.4kOe, and (BH) max=9.0MGOe. As a presentation of one exchange spring magnet, it is Nd<sub>8</sub> Fe<sub>78</sub> Co<sub>7</sub> V<sub>2</sub> B<sub>5</sub>. The presentation was chosen and the quenching thin band was produced. The magnetic properties after heat treatment of this thin band were Br=12.1kG, iHc=5.0kOe, and (BH) max=19.7MGOe. Moreover, the diameter of crystal grain of a thin band was [ about 7.5 area % and the soft magnetism crystal phase of 10-40nm and a soft magnetism amorphous phase ] about 60 area %. This thin band was ground and a screen and magnetic powder (B) were produced for fine-particles grain size to 40 micrometers or less (mean particle diameter of 30 micrometers). The magnetic properties of the compression-molding bond magnet of use of only magnetic powder (B) were Br=9.3kG, iHc=4.6kOe, and (BH) max=11.5MGOe. The mixing ratio of magnetic powder was changed, the bond magnet was produced by the same approach as the above, and the magnetic properties and magnetic powder filling factor were measured. The result is shown in drawing 4. This drawing 4 shows that, as for a filling factor, magnetic powder (B) takes the maximal value near 40%. Moreover, Br made into the purpose of this invention is 8 or more kGs, and iHc is 5kOe(s). In the case of this example, the mixed ratio of the magnetic powder (B) with which (BH) max is satisfied of 11 or more MGOes serves as 30 - 70% of range above. Furthermore, the highest energy products were 12.3MGOe(s) near 40%.

[0038] Although it was the combination of the same magnetic powder as example of comparison 1 example 1, the bond magnet was produced like the example 1, having set up both the same level (A), i.e., magnetic powder, and (B) for fine-particles grain size among 50-150 micrometers, and having used the mean diameter as 100 micrometers, and magnetic properties etc. were measured. In this case, the greatest KUNIKKU was produced, and although the magnitude of KUNIKKU decreased also in 90%, it accepted for whether being \*\*, so that the point of inflection (KUNIKKU) which was already conspicuous might begin to have arisen from the demagnetization curve of 10% of mixed ratios of magnetic powder (B) and it might illustrate to drawing 5 in 50%. Moreover, the filling factor was not concerned with the mixed ratio, but was almost as fixed as 79% order, and iHc showed an average change to which Br is also proportional to a mixed ratio, though it was natural. In this case, the value of (BH) max does not have the semantics of calculation by existence of KUNIKKU, and cannot present practical use with a bond magnet easily.

[0039] The magnetic powder (B) and (exchange spring magnet magnetic powder) of example of comparison 2 example 1 are changed into what does not have a residual amorphous phase. Magnetic powder (B) Nd<sub>4</sub> Dy<sub>1</sub> Fe<sub>72.5</sub> Co<sub>3</sub> Ga<sub>1</sub> B<sub>18.5</sub> namely, as a Fe<sub>3</sub> B-Nd<sub>2</sub> Fe<sub>14</sub> B die change spring magnet of the type which does not have the residual amorphous phase of the becoming presentation When the magnetic properties of a heat treated quenching thin band were measured, they were Br=11.9kG, iHc=5.0kOe, and (BH) max=17.8MGOe. Magnetic powder (A) was chosen like the example 1, carried out grain refining of the magnetic powder (A) among 100-250 micrometers (mean particle diameter of 175

micrometers), and adjusted magnetic powder (B) to 50 micrometers or less (mean particle diameter of 40 micrometers). It is  $iH_c=1.7kOe$ , although it was  $Br=9.2kG$  when magnetic powder (B) produced the bond magnet of 100% of single presentation. As compared with the value of a quenching thin band, it fell sharply, and became  $(BH)_{max}=4.2MGOe$  and a low value. On the other hand, the bond magnet of the single presentation at the time of carrying out grain refining of the grain size of magnetic powder (B) among 100-250 micrometers (175 micrometers of mean diameters) Since it has the magnetic properties which were excellent in  $Br=9.3kG$ ,  $iH_c=4.8kOe$ , and  $(BH)_{max}=10.1MGOe$  Magnetic properties are considered to fall greatly in order to receive the effect of grinding distortion greatly, if grinding grain size becomes small, since magnetic powder (B) does not have a residual amorphous phase. The bond magnet by mixed magnetic powder with magnetic powder (A) is produced by the same approach as an example 1 using magnetic powder (B) with a mean particle diameter of 40 micrometers. When the magnetic properties etc. are measured, as shown in drawing 6 , although the ratio of magnetic powder (B) was seen, the improvement in  $Br$  on near 30%, and accompanying the improvement beyond the average of a filling factor, and it Since the fall of  $iH_c$  was large, the value of  $(BH)_{max}$  in this point does not exceed an average-straight line, and was a low value of  $7.7MGOe$  and this invention out of range.

[0040] Although a residual amorphous phase has the magnetic powder (B) and a (exchange spring magnet) of example of comparison 3 example 2  $iH_c$  is  $3.5kOe(s)$ . It changes into the thing of the following, namely, is magnetic powder (B)  $Nd_7 Fe_{85}Co_4 B_4$  As an  $\alpha Fe-Nd_2 Fe_{14}B$  die change spring magnet which has the residual amorphous phase of a presentation When the magnetic properties of a heat treated quenching thin band were measured, they were  $Br=12.1kG$ ,  $iH_c=3.2kOe$ , and  $(BH)_{max}=11.9MGOe$ . Moreover, the diameter of crystal grain was [ about 9.5 area % and the soft magnetism crystal phase of 10-50nm and a soft magnetism amorphous phase ] about 75 area %s. Magnetic powder (A) was chosen like the example 2, carried out grain refining of the magnetic powder (A) among 100-250 micrometers (mean particle diameter of 175 micrometers), and adjusted magnetic powder (B) to 50 micrometers or less (mean particle diameter of 35 micrometers). When magnetic powder (B) produced the bond magnet of 100% of single presentation, they were  $Br=9.7kG$ ,  $iH_c=3.0kOe$ , and  $(BH)_{max}=7.0MGOe$ . When the bond magnet by magnetic powder (A) and mixed magnetic powder with (B) is produced by the same approach as an example 2 and the magnetic properties etc. are measured, as shown in drawing 7 , although the ratio of magnetic powder (B) was seen, the improvement in  $Br$  on near 40%, and accompanying the improvement beyond the average of a filling factor, and it the fall of  $iH_c$  which shows a mixed average change -- remarkable -- this -- also in 40% of point,  $(BH)_{max}$  was the low value of  $9.8MGOe(s)$  and this invention out of range.

[0041] The magnetic powder (A) used for examples 1 and 2 and the examples 1-3 of a comparison and the property of (B) are shown in Table 1. In addition, the example shown as the above mentioned embodiment is also shown collectively.

[0042]

[Table 1]

		実施 態様	実 施 例		比 較 例			
			1	2	1	2	3	
(A)	磁粉	希土類元素含有量(at.%)	11	8.5	9.5	8.5	8.5	9.5
		薄帯の <i>iHc</i> (kOe)	12.9	11.1	12.9	11.1	11.1	12.9
		薄帯の <i>Br</i> (kG)	9.7	8.6	8.4	8.6	8.6	8.4
		薄帯の <i>(BH) max</i> (MG0e)	20.1	15.2	14.7	15.2	15.2	14.7
		平均粉体粒径 (μm)	150	175	200	100	175	175
(B)	磁粉	希土類元素含有量(at.%)	7.5	7	8	7	5	7
		薄帯の <i>iHc</i> (kOe)	4.8	4.7	5.0	4.7	5.0	3.2
		薄帯の <i>Br</i> (kG)	11.9	11.6	12.1	11.6	11.9	12.1
		薄帯の <i>(BH) max</i> (MG0e)	18.8	18.6	19.7	18.6	17.8	11.9
		結晶粒径 (nm)	10~50	20~60	10~40	20~60	10~60	10~50
		アモルファス相 (面積%)	約 8	約 9	約 7.5	約 9	0	約 9.5
		軟磁性結晶相 (面積%)	約 60	約 65	約 60	約 65	約 70	約 75
		平均粉体粒径 (μm)	50	35	30	100	40	35

[0043]

[Effect of the Invention] Although rare earth elements are a low content by the compound effectiveness according [ this invention ] to the combination of specific magnetic powder an above-stated passage, *Br* is 8 or more kGs and *iHc* is 5kOe(s). *(BH) max* offers economically above the high performance Nd system bond magnet with which are satisfied of 11 or more MGOes cheaply.

[Translation done.]

**\* NOTICES \***

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1.This document has been translated by computer. So the translation may not reflect the original precisely.

2.\*\*\*\* shows the word which can not be translated.

3.In the drawings, any words are not translated.

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**DESCRIPTION OF DRAWINGS**

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[Brief Description of the Drawings]

[Drawing 1] It is the demagnetization curve of the rare earth bond magnet in (magnetic powder A) / (B) =50/50 in an embodiment.

[Drawing 2] It is the graph which shows the magnetic properties and the magnetic powder filling factor of a rare earth bond magnet in an embodiment.

[Drawing 3] It is the graph which shows the magnetic properties and the magnetic powder filling factor of a rare earth bond magnet in an example 1.

[Drawing 4] It is the graph which shows the magnetic properties and the magnetic powder filling factor of a rare earth bond magnet in an example 2.

[Drawing 5] It is the demagnetization polar-line of the rare earth bond magnet in (magnetic powder A) / (B) =50/50 in the example 1 of a comparison.

[Drawing 6] It is the graph which shows the magnetic properties and the magnetic powder filling factor of a rare earth bond magnet in the example 2 of a comparison.

[Drawing 7] It is the graph which shows the magnetic properties and the magnetic powder filling factor of a rare earth bond magnet in the example 3 of a comparison.

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(54) 【発明の名称】 希土類ボンド磁石

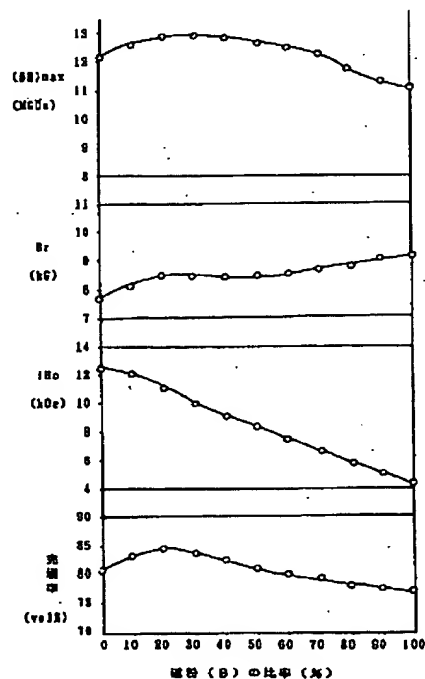
(57) 【要約】

【課題】 経済的で高性能である希土類ボンド磁石を提供する。

【解決手段】 下記磁粉 (A)、(B) 及び結合用樹脂からなり、 $B_r$  が 8 kG 以上、 $i H_c$  が 5 kOe 以上、 $(B H)_{max}$  が 11 MG0e 以上の磁気特性を有する希土類ボンド磁石。

(A)  $Nd_2Fe_{14}B$  型結晶を含む希土類系磁石材料であって、希土類元素の含有率が 8~11 at. %、 $i H_c$  が 7 kOe 以上の急冷薄帯の粉碎粉で平均粒径が 100  $\mu m$  以上の磁粉、

(B) 希土類元素の含有率が 8 at. % 以下、 $i H_c$  が 3.5~6.0 kOe で、 $B_r$  が 10 kG 以上の、結晶粒径が 10~100  $\mu m$  に制御されたソフト磁性相とハード磁性相及び 10 面積% 以下のアモルファス相とから構成される交換スプリング磁石薄帯の粉碎粉で平均粒径 50  $\mu m$  以下の磁粉。



(2)

## 【特許請求の範囲】

【請求項1】 下記磁粉（A）と（B）との混合磁粉及び結合用樹脂を主たる構成成分とし、残留磁束密度 $B_r$ が8kG以上、保磁力 $iH_c$ が5kOe以上、エネルギー積 $(BH)_{max}$ が11MGOe以上の磁気特性を有することを特徴とする希土類ボンド磁石。

（A） $Nd_2Fe_{14}B$ 型結晶を含む希土類系磁石材料であって、希土類元素の含有率が8～11at.%, 保磁力 $iH_c$ が7kOe以上の急冷薄帯の粉碎粉で平均粒径が100 $\mu m$ 以上の磁粉、

（B）希土類元素の含有率が8at.%以下、保磁力 $iH_c$ が3.5～6.0kOeで、残留磁束密度 $B_r$ が10kG以上の、結晶粒径が10～100nmに制御されたソフト磁性相とハード磁性相及び10面積%以下のアモルファス相とから構成される交換スプリング磁石薄帯の粉碎粉で平均粒径50 $\mu m$ 以下の磁粉。

【請求項2】 圧縮成形により得られた請求項1記載の希土類ボンド磁石。

## 【発明の詳細な説明】

## 【0001】

【発明の属する技術分野】本発明は、高性能でかつ経済的な希土類ボンド磁石に関し、更に詳しくは、希土類元素低含有量であるにも拘らず、残留磁束密度 $B_r$ が8kG以上、保磁力 $iH_c$ が5kOe以上であり、エネルギー積 $(BH)_{max}$ が11MGOe以上と高い性能を有する希土類系ボンド磁石に関する。

## 【0002】

【従来の技術】従来、希土類系ボンド磁石は、Nd系等方性圧縮成形磁石を中心に、電子電気部品としてモータ用磁石の形で多用されている。特にコンピュータ搭載機器であるハードディスクドライブ（HDD）、CD-ROM、同周辺機器であるプリンタ、スキャナ、及び携帯通信機器であるページャ、セルラなどに大量に使用されている。

【0003】しかしながら、これらの機器の小型軽量化に伴い、より強力でかつ経済的な磁石の要求が近年特に高まっている。希土類系焼結磁石（Nd系、Sm系）やSm系異方性ボンド磁石は、Nd系等方性ボンド磁石よりも高エネルギー積を有する強力磁石であるが、経済性に劣るため上記機器のモーター用途には殆ど使用されていない。

【0004】Nd系等方性ボンド磁石の原料磁粉としては、現在のところ、米国GM社が開発したMQP（商品名）磁粉（MQI社製）が唯一工業規模で供給されており、このMQP磁粉の内でも、特にMQP-Bグレードが主体的に使用されている。このMQP-B磁粉の一般的な組成は $Nd_2Fe_{14}B$ 型結晶構造の化学量論組成付近の $Nd_{12}Fe_{76.5}Co_{5.5}B_6$ であり、磁気特性は、公称で $B_r=8.2kG$ 、 $iH_c=9.0kOe$ 、 $(BH)_{max}=12.0MGOe$ であり、この磁粉を使用した圧縮

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成形ボンド磁石（MQI-B10）の磁気特性は、 $B_r=6.9kG$ 、 $iH_c=9.0kOe$ 、 $(BH)_{max}=10.0MGOe$ である（MQI社カタログによる。）。

【0005】また、特開平8-124730には、 $Nd_2Fe_{14}B$ 化学量論組成付近の $Nd_{12}\pm 0.5at.\%$ 、保磁力 $iH_c=10kOe$ の急冷粉体と、結晶粒径が20～50nmに制御されたソフト磁性相とハード磁性相から構成される交換スプリング磁石粉体とを混合し、これを樹脂で固めた保磁力4～10kOeの低保磁力希土類樹脂磁石が記載されている。しかし、上記発明の目的は、要約に記載されている通り、多極着磁性に優れた希土類樹脂磁石を提供することであり、このため、粉体混合により保磁力を低下させることが主眼となっている。したがって、実施例に記載された磁気特性も、上記MQI-B10の磁気特性を越えるものではない。以上の如く、近年ますます高磁力でかつ経済的な磁石の要求が高まっているにも拘らず、性能及び経済性の両面で十分に満足し得る磁石は未だ提案されていないのが実情である。

## 【0006】

【発明が解決しようとする課題】本発明は、上記実情に鑑み、現行のMQI-B10より高い $B_r$ を有し、角形性を損なわない程度の $iH_c$ を有し、結果としてMQI-B10よりも高い $(BH)_{max}$ を有するボンド磁石を経済的に提供することを課題とする。

## 【0007】

【課題を解決するための手段】一般に永久磁石の理論的なエネルギー積は、 $(BH)_{max}=0.25\times B_r^2$ で表される。したがって、MQI-B10よりも高エネルギー積を有するボンド磁石を得るためには、より高い $B_r$ を有する磁粉を使用することが不可欠となる。この際に、 $iH_c$ は理論的には、 $iH_c>0.5\times B_r$ を満足すれば、角形性を損なわず、したがってエネルギー積を低下せしめることはないのので、この条件を満足する限りは、上記のMQP-B磁粉よりも低い $iH_c$ を有する磁粉を用いることができる。

【0008】このような磁粉の一つとして、近年特に研究開発が盛んな交換スプリング磁石がある。交換スプリング磁石は、鉄もしくは鉄化合物と $Nd_2Fe_{14}B$ 型正方晶化合物との交換相互作用により、磁気的なスプリング現象を示すもので、その特徴は、低希土類元素量と高い残留磁束密度 $B_r$ を有することであり、コストパフォーマンスに優れた磁石となる可能性が高い。

【0009】即ち、Nd等の希土類元素量が10原子%未満の希土類-鉄-ボロン系交換スプリング磁石合金は、例えば、米GM社が開発した市販の“MQP”（商品名）のようにNd等の希土類量が化学量論組成に近い11～15原子%の希土類-鉄-ボロン系磁石合金に比べ、磁気特性上のポテンシャルが高く、また、高価な希土類の量を低減できるため経済的であるという特徴を有する。

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【0010】このNd等の希土類元素量が10原子%未満の希土類-鉄-ボロン系交換スプリング磁石合金には、軟磁性相として上記の $\alpha$ FeやbccFeを含む系と、Fe<sub>3</sub>BやFe<sub>2</sub>Bを含む系とがある。学術文献等によると、前者は、一般に残留磁束密度Brが10~13kGと高いが保磁力iHcは高々3.5kOe未満と低いものであり、後者は、一般に保磁力iHcが3.5~7.7kOeと比較的高いが、残留磁束密度Brが10kG程度以下であるため、上記MQP-B(Br=8.2)と比べると残留磁束密度Brは高いが、前者の $\alpha$ Fe主体系に比べて低いものであった。

【0011】そこで、本発明では、2種類の磁粉(A)と(B)を混合し、これを用いてボンド磁石の磁気特性を改良することを着想した。すなわち、一方の磁粉として、より高いBrを有し、残存非晶質相が10面積%以下存在する $\alpha$ Fe-NdFeB系交換スプリング磁石粉末(B)を選択し、もう一方の磁粉として、上記MQP-B磁粉よりも希土類含有量が少なく経済性に富み、磁粉(B)に比してBrは低いがいHcが7kOe以上と高い既知の磁粉(A)を選択し、種々実験を行った結果、ボンド磁石の磁気特性として、Br $\geq$ 8kG、iHc $\geq$ 5kOe、(BH)max $\geq$ 11MGOeを実現したものである。すなわち、上記のボンド磁石MQI-B10に比して、iHcは低いもののBrと(BH)maxに優れ、かつ経済性に優れた磁石を提供し得ることを見出し、本発明を完成するに至った。

【0012】すなわち、本発明は下記磁粉(A)と(B)との混合磁粉及び結合用樹脂を主たる構成成分とし、残留磁束密度Brが8kG以上、保磁力iHcが5kOe以上、エネルギー積(BH)maxが11MGOe以上の磁気特性を有することを特徴とする希土類ボンド磁石を内容とするものである。(A)Nd<sub>2</sub>Fe<sub>14</sub>B型結晶を含む希土類系磁石材料であって、希土類元素の含有率が8~11at.%、保磁力iHcが7kOe以上の急冷薄帯の粉碎粉で平均粒径が100 $\mu$ m以上の磁粉、(B)希土類元素の含有率が8at.%以下、保磁力iHcが3.5~6.0kOeで、残留磁束密度Brが10kG以上の、結晶粒径が10~100nmに制御されたソフト磁性相とハード磁性相及び10面積%以下のアモルファス相とから構成される交換スプリング磁石薄帯の粉碎粉で平均粒径50 $\mu$ m以下の磁粉。

【0013】本発明に使用される磁粉(B)としては、本発明者らによって先に開発され特許出願中(特願平8-226021)のものが好適であり、具体的には、式R<sub>x</sub>Fe<sub>100-x-y-z-w</sub>Co<sub>y</sub>M<sub>z</sub>B<sub>w</sub>〔但し、Rは、Nd、Pr、Dy、Tb及びCeから選ばれた希土類元素の一種又は二種以上、Mは、Ti、V、Cr、Zr、Nb、Mo、Hf、Ta、W、Mn、Cu、Ga、Zn、In、Sn、Bi、Ag及びSiから選ばれた元素の一種又は二種以上、x、y、z及びwは、それぞれ原子比

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で $5 \leq x \leq 10$ 、 $1.0 \leq y \leq 9$ 、 $0.1 \leq z \leq 5$ 、 $2 \leq w \leq 7$ 、かつ、 $9 \leq (x+w)$ 、 $5 < (y+z)$ 〕で表わされる組成を有し、且つ、 $\alpha$ Fe、bccFe及びこれらと上記Mとの固溶体を含む軟磁性結晶相とNd<sub>2</sub>Fe<sub>14</sub>B<sub>1</sub>型正方晶系結晶からなる硬磁性結晶相とのそれぞれが、軟磁性非晶質相中に析出している合金組織を有しており、前記軟磁性非晶質相が全合金組織に対し10面積%以下であって、残部が前記軟磁性結晶相と前記硬磁性結晶相であり、且つ、前記軟磁性結晶相が全結晶組織に対し少なくとも50面積%であって、残部が前記硬磁性結晶相であることを特徴とする希土類-鉄-ボロン系磁石合金である。上記技術によれば、本発明に用いられる磁粉(B)、すなわち、希土類元素の含有率が8at.%以下、保磁力iHcが3.5~6.0kOeで、残留磁束密度Brが10kG以上の、結晶粒径が10~100nmに制御されたソフト磁性相とハード磁性相及び10面積%以下のアモルファス相とから構成される交換スプリング磁石薄帯の粉碎粉で平均粒径50 $\mu$ m以下の磁粉を容易に調製することができる。

【0014】磁粉(B)の希土類元素の含有率が8at.%を越えると、相対的に鉄属の含有量が低下するため本発明の磁粉(B)の要件である10kG以上の高Brが得難くなり、一方、下限は特に制限されないが、iHcを3.5kOe以上に保つためには、希土類元素含有率は5at.%以上であることが好ましい。また、保磁力iHcが3.5kOe未満では、混合磁粉によるBrの上昇効果よりも、iHcの比例的低下の度合が大きくなり、結果として(BH)max $\geq$ 11MGOeを達成できず、一方、6.0kOeを越えると、一般に相対的にBrが低下することが多くなり、磁粉(B)の要件である10kG以上の高Brが得難くなる。好ましくは5.5kOeである。更に、残留磁束密度Brが10kG未満ではBrが小さすぎ、結果として、本発明の目的とする高性能のボンド磁石が得られず、一方、上限は特に制限されないが、iHcを3.5kOe以上というバランスを考慮すると、15kG以下となるのが通常である。磁粉(B)は、合金組織がナノコンポジット構造になっており、ハード磁性相であるNd<sub>2</sub>Fe<sub>14</sub>B型結晶の大きさは10~100nmであり、ソフト磁性相である $\alpha$ Feや鉄化合物の結晶粒径も10~100nmである。これらの結晶粒径が10nm未満では一般に超常磁性的ふるまいが多くなり、Brの低下を招き、一方、100nmを越えると保磁力の低下が著しくなる。また、10面積%以下、好ましくは10~1面積%を占める残部のアモルファス相がこれらの結晶相を取り囲んでいるので、合金を粉砕し、例えば平均粒径50 $\mu$ m以下の粉体としても、著しく磁気特性を劣化させることはない。残部のアモルファス相が10面積%を越えると、軟磁性結晶相と硬磁性結晶相との磁気的交換相互作用を弱め、保磁力の低下や減磁曲線に変曲点をもたらす。また、1面積%未満となると、磁粉とする粉

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碎時に歪を受けやすくなり、保磁力  $iH_c$  の大巾低下を招く傾向がある。更に、軟磁性結晶相が全結晶組織に対し50面積%未満となると10kG以上の高  $B_r$  が得難くなり、一方、上限は特に制限されないが、 $iH_c$  が3.5kOe以上となるためには硬磁性結晶相が10面積%以上は必要なため、差引すると80面積%が一般的な上限となる。

【0015】本発明に用いられる磁粉(A)は、希土類元素を8~11at.%含み、 $iH_c$  が7kOe以上の既知の磁石材料からなり、主として液体急冷法と熱処理(最適急冷を施した場合は、熱処理工程を省略できることもある)によって製造される。磁粉(A)の合金組成に関しては、本発明においては、経済性の観点から希土類元素量を限定するだけでよく、他の限定は特に設ける必要がない。特に、遷移金属側の組成は、次に例示するように、種々の有効な添加元素を含んでいてもよい。

【0016】例えば、特開昭64-703号には、種々の合金が開示されており、例えば、 $Nd_{11}Fe_{79}Nb_2Ta_2B_6$  の組成の急冷リボンの磁気特性は、 $B_r = 8.3kG$ 、 $iH_c = 14.9kOe$ 、 $(BH)_{max} = 14.0MG0e$ と記載されている(第1表・No24)。また、特開昭64-7502号には、 $Nd_8Fe_{70}Co_{10}Zr_3Ti_1B_8$  の合金リボンの磁気特性が、 $B_r = 8.6kG$ 、 $iH_c = 11.1kOe$ 、 $(BH)_{max} = 15.2MG0e$ と記載されている(第2表・No5)。

【0017】更に、特公平4-47024号にも種々の合金が開示されており、例えば、 $Nd_{11}Fe_{72}Co_8V_{1.5}B_{7.5}$  の組成の合金は、急冷薄帯で $B_r = 9.7kG$ 、 $iH_c = 12.9kOe$ 、 $(BH)_{max} = 20.1MG0e$ の磁気特性を有すると記載されている(第1表・No4)。これらの合金は本発明における磁粉(A)として使用できる。

【0018】ここで、磁粉(A)の希土類元素含有率を8~11at.%に限定した理由は、上記MQP-B磁粉に比べて、高価な希土類元素の使用量を少なくするという経済的な理由のみならず、上記の明細書に記載されているごとく、 $iH_c$  が十分高い上に $(BH)_{max}$  もより大きい上、着磁性にも優れた磁粉を得ることができるからである。さらに、 $iH_c$  を7kOe以上とした理由は、磁粉(B)の保磁力が低く一般的には6kOe程度が上限のため、磁粉混合効果によりボンド磁石の減磁曲線の角形性を損なわない程度に十分な保磁力を確保するためである。 $iH_c$  の上限は特に制限されないが、ボンド磁石の着磁性を考慮すると17kOe以下が好ましい。

【0019】磁粉(A)は、一般的に $Nd_2Fe_{14}B$ 型結晶単一相もしくは該主相と微量粒界相との混合相とされているが、結晶粒径は数10nm大である。しかし、これらの合金は粉碎による歪みの影響を受けやすいため、粉碎粒度を下げるると保磁力が徐々に低下するので、実用上は100 $\mu m$ 前後が粉碎粉体粒径の限界とされて

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いる。

【0020】

【作用】本発明は、磁粉(B)を平均粒径50 $\mu m$ 以下に調整し、磁粉(A)を平均粒径100 $\mu m$ 以上に調整し、(A)対(B)の混合比率を重量比で1対9から9対1の間に設定した混合磁粉を用いて圧縮成形により樹脂ボンド磁石を作製したところ、磁石の減磁曲線がほぼくびれの無い、すなわち、減磁曲線上に目立った変曲点のないスムーズな曲線となることを知見し、そして、このスムーズ減磁曲線により、磁気エネルギー積に優れたボンド磁石を実現したものである。

【0021】粒径分布の異なる磁粉を混合し圧縮成形して、良好な特性を異方性ボンド磁石を得る例として、日本応用磁気学会誌、20、221-224(1996)に、北沢らにより $Sm_2Co_{17}$ 系磁粉(粒径大)と、 $Sm_2Fe_{17}N_3$ 系磁粉(粒径小)との混合組合せが報告されている。該報告によれば、混合比率全域にわたってほぼくびれの無いスムーズな減磁曲線を得ており、原因として、磁粉間に静磁的な磁気的相互作用が働いたものと考察している。また、ある混合比のところで、粒度分布の差に起因して、ボンド磁石中に占める全磁粉の体積比率が上がるため、 $B_r(BH)_{max}$ の高い良好な磁気特性が実現することも報告されている。

【0022】したがって、本発明のNd系合金を用いた等方性ボンド磁石においても、実験結果から磁粉間の磁気的相互作用が働いてスムーズな減磁曲線が得られたものと推察される。さらに、2種類の磁粉の粒径に依存するが、以下の実施例に示すように、ある混合比率のところで全磁粉の体積比率(磁粉の充填率)が極大値を有し、等方性ボンド磁石の磁気特性、特に $B_r$ と $(BH)_{max}$ が単純平均の値よりも向上することも確認された。

【0023】

【発明の実施の形態】磁粉(B)は、本発明者らが先に特許出願した交換スプリング磁石の粉末が好適であり、一般には、目的組成の合金を溶解法で作製し、液体急冷法などでアモルファス状態にしたのち、熱処理することにより、軟磁性非晶質相から硬磁性結晶相と軟磁性結晶相を適度な大きさに析出させ、その結果として、これら3つの相が共存した状態にし、これを粉碎して得られる粉末である。なお、熱処理と粉碎の順序は前後してもよい。

【0024】磁粉(A)は、既知の急冷薄帯合金の粉末でよいが、前記の理由で希土類元素の含有率が8~11at.%で、保磁力 $iH_c$ が7kOe以上の条件を有する必要がある。この粉末も一般には、目的組成の合金を溶解法で作製し、液体急冷法などでアモルファス状態にしたのち、熱処理し粉碎することにより得られる。この場合も、熱処理と粉碎の順序は前後してもよい。しかし、この合金は希土類含有率の範囲などの組成上の制限が主因

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で、一般に単一相もしくは主相と微量粒界相との混合相からなっており、上記の磁粉(B)のごとく、軟磁性結晶相や軟磁性非晶質相は基本的な構成相とはなっていない。ただし、後者の2つの相が粒界相や不純物相としてごく微量の存在は許されることは言うまでもない。

【0025】混合磁粉(A+B)は、磁粉(A)の粉体粒径を磁粉(B)の粒径よりも大きく設定して混合することにより、ボンド磁石中の磁粉の充填密度を高める必要がある。磁粉(A)の粉体粒径は、平均値が $100\mu\text{m}$ 以上に設定すると高特性ボンド磁石が得られる。より好適には、 $100\sim 200\mu\text{m}$ である。磁粉(B)の平均粒径は、 $50\mu\text{m}$ 以下に設定する。より好適には、 $20\sim 50\mu\text{m}$ である。これら磁粉の粉碎と混合は一般的な手法で行うことができる。例えば、ボールミルやアトライトミルによる粉碎、振動ふるいによる分級、リボンブレンダーやプラネタリブレンダーによる攪拌混合である。磁粉(A)と(B)の混合比率は、最も高いエネルギー積 $(BH)_{\text{max}}$ が得られるように設定する。この比率は、両磁粉の有する磁気特性と平均粒径によって、最適な数値が変動するので、予め実験により良く把握しておく必要がある。次に、上記の攪拌混合の前もしくは後に結合用樹脂(バインダーポリマー)等を付加し、成形用材料とするためのコンパウンディングを行うことができる。

【0026】結合用樹脂としては、圧縮成形磁石を作製する場合は、エポキシ系やフェノール系の熱硬化性樹脂が一般的であり、射出成形磁石を作製する場合は、ポリアミド(ナイロン)系、ポリフェニレンサルファイド

(PPS)系や液晶樹脂系の熱可塑性樹脂が一般的である。さらに、押出成形やカレンダーロール成形も適切なバインダーを選択すれば実施可能である。本発明の希土類ボンド磁石は、前記の作用に記載した効果をより効率的に発揮でき、高磁気特性を得られる点で特に圧縮成形により製造するのが好ましい。

【0027】以下、圧縮成形磁石を主体として詳細に説明する。圧縮成形用コンパウンドには、成形を容易にしたり、磁気特性を十分に引き出す目的で、必要により、バインダーポリマーの他に、可塑剤、滑剤、カップリング剤など周知の添加物を少量含めることができる。

【0028】圧縮成形は、従来の等方性ボンド磁石を作製する方法により行うことができる。すなわち市販のプレス成形機を用いて製造することができるが、特に、プレス圧力は、工業的に可能な限り高めに設定する方が充填密度が上がり、等方性ボンド磁石の高 $B_r$ 化、ひいては高 $(BH)_{\text{max}}$ 化をもたらすので有利である。

【0029】圧縮成形された磁石は、次の熱処理工程により樹脂硬化され、次いで着磁されるのが通常である。しかし、場合によっては、樹脂硬化のあと他部品と一体化されたのちに着磁されることもある。いずれの場合もパルス電流で着磁されるのが一般的である。作製された

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ボンド磁石の磁気特性は、一般的には、 $B-H$ カーブトレサで測定される。磁石の安定性評価に必要な不可逆損失率などは、磁束計で測定される。

【0030】次に、本発明の代表的な実施態様について具体例を挙げて説明する。高保磁力磁粉である磁粉

(A)として、 $\text{Nd}_{11}\text{Fe}_{72}\text{Co}_8\text{V}_{1.5}\text{B}_{7.5}$ なる組成を選択し、その急冷薄帯を作製したのち、 $650^\circ\text{C}$ 、5分間の熱処理を施し、粉碎し粉末を作製した。この合金の粉碎前のリボンの磁気特性は、 $B_r=9.7\text{kG}$ 、 $iH_c=12.9\text{kOe}$ 、 $(BH)_{\text{max}}=20.1\text{MG0e}$ であった。一方、交換スプリング磁石の粉末である磁粉(B)として、 $\text{Nd}_{7.5}\text{Fe}_{83}\text{Co}_{4.5}\text{Nb}_1\text{B}_4$ なる組成の合金を選んだ。この合金を液体急冷法によりアモルファスとしたのち、 $740^\circ\text{C}$ 、3分間の熱処理を施した。結晶粒径は $10\sim 50\text{nm}$ 、軟磁性アモルファス相は約8面積%、軟磁性結晶相は約60面積%であった。この合金の粉碎前のリボンの磁気特性は、 $B_r=11.9\text{kG}$ 、 $iH_c=4.8\text{kOe}$ 、 $(BH)_{\text{max}}=18.8\text{MG0e}$ であった。

【0031】磁粉(B)を粉体粒度 $10\mu\text{m}$ 以上、 $70\mu\text{m}$ 以下(平均粒径 $50\mu\text{m}$ )にふるい、磁粉(A)を粉体粒度 $100\mu\text{m}$ 以上、 $200\mu\text{m}$ 以下(平均粒径 $150\mu\text{m}$ )にふるって粒度調整した。次に、磁粉(A)と磁粉(B)をよく混合し、全体の磁粉量に占める磁粉(B)の重量比率が、0、10、20、30、40、50、60、70、80、90、100%となるよう設定した。次にエポキシ樹脂約2重量%をバインダーとして用い、 $7\text{t}/\text{cm}^2$ の圧力をかけ圧縮成形ボンド磁石を作製し、室温の磁気特性を $BH$ カーブトレサで測定した。磁粉の充填率は、ボンド磁石の体積と密度から算出した。なお、磁粉(A)単独使用[磁粉(B):0%]の圧縮成形ボンド磁石の磁気特性は、 $B_r=7.7\text{kG}$ 、 $iH_c=12.5\text{kOe}$ 、 $(BH)_{\text{max}}=12.2\text{MG0e}$ であった。また、磁粉(B)単独使用[磁粉(B):100%]の圧縮成形ボンド磁石の磁気特性は、 $B_r=9.2\text{kG}$ 、 $iH_c=4.5\text{kOe}$ 、 $(BH)_{\text{max}}=11.1\text{MG0e}$ であった。

【0032】図1に磁粉(A)と磁粉(B)との混合比率が各50%の場合の減磁曲線を示す。この図1から、磁気特性の異なる磁粉を混合した場合でも、粉体粒度を適切に調整すれば、減磁曲線上に目立った変曲点のない比較的スムーズな曲線が得られ、本発明においても、異種磁粉間に磁氣的相互作用が働いていることが分かる。このようなほぼ変曲点のない減磁曲線は、上記総ての混合比率のボンド磁石において得られた。

【0033】次に、図2に各混合比の磁粉を使用したボンド磁石の磁気特性と磁粉充填率を示す。図2から、充填率は磁粉(B)が20%付近で極大値をとることが分かる。これに伴い、残留磁束密度 $B_r$ も同様に平均値よりも大きくなるが、磁粉(B)の $B_r$ が磁粉(A)の $B$

(6)

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rよりも大きいため、50%以上からは少しずつ上昇する。保磁力*iHc*はほぼ平均値直線に従う傾向を示した。結果として、最大エネルギー積 $(BH)_{max}$ は磁粉(B)が20%付近で極大値をとるが、その後も*Br*の変化に影響され急激に落ちることなく、磁粉(B)が70%程度まではゆるやかな低下を示す。したがって、本発明の目的とする、*Br*が8kG以上、*iHc*が5kOe以上、 $(BH)_{max}$ が11MG0e以上を満足する磁粉(B)の混合比率は、本実施態様の場合10~90%の範囲となる。また、最高のエネルギー積は、20%付近の13.0MG0eであった。

## 【0034】

【実施例】次に、実施例および比較例を挙げて更に詳細に説明するが、これらは本発明の範囲を何ら制限するものではない。

## 実施例1

高保磁力磁粉である磁粉(A)として、 $Nd_{8.5}Fe_{70}Co_{10}Zr_3Ti_{0.5}B_8$ なる組成合金を選び、その急冷薄帯を作製した。この薄帯の熱処理後の磁気特性は、*Br*=8.6kG、*iHc*=11.1kOe、 $(BH)_{max}$ =15.2MG0eであった。一方の交換スプリング磁石の粉末である磁粉(B)として、 $Nd_6Pr_1Fe_{83.5}Co_4Ti_1Ga_{0.5}B_4$ なる組成の合金を選んだ。この合金の薄帯リボンの熱処理後の磁気特性は、*Br*=11.6kG、*iHc*=4.7kOe、 $(BH)_{max}$ =18.6MG0eであった。また結晶粒径は20~60nm、軟磁性アモルファス相は約9面積%、軟磁性結晶相は約65面積%であった。

【0035】磁粉(B)の粉体粒度を50μm以下(平均粒径35μm)にふるい、磁粉(A)の粉体粒度を100μm以上、250μm以下(平均粒径175μm)にふるって粒度調整した。その後は、前記実施の態様と同様に混合磁粉によるボンド磁石を作製し、磁気特性等を測定した。なお、磁粉(A)単独使用の圧縮成形ボンド磁石の磁気特性は、*Br*=6.7kG、*iHc*=10.7kOe、 $(BH)_{max}$ =9.3MG0eであった。また、磁粉(B)を単独使用した圧縮成形ボンド磁石の磁気特性は、*Br*=9.0kG、*iHc*=4.5kOe、 $(BH)_{max}$ =10.8MG0eであった。

【0036】図3に各混合比の磁粉を使用したボンド磁石の磁気特性と磁粉充填率を示す。図3から、充填率は磁粉(B)が30%付近で極大値を取ることが分かる。したがって、本発明の目的とする*Br*が8kG以上、*iHc*が5kOe以上、 $(BH)_{max}$ が11MG0e以上を満足する磁粉(B)の混合比率は、本実施例の場合は、20~40%の範囲となる。また、最高のエネルギー積は30%付近の12.0MG0eであった。

## 【0037】実施例2

高保磁力側の磁粉(A)として、 $Nd_9Dy_{0.5}Fe_{70.5}Co_{10}Ni_1Nb_3B_6$ なる組成を選び、その急冷

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薄帯を作製した。この薄帯の熱処理後の磁気特性は、*Br*=8.4kG、*iHc*=12.9kOe、 $(BH)_{max}$ =14.7MG0eであった。この薄帯を粉碎し、粉体粒度を100μm以上、300μm以下(平均粒径200μm)にふるい、粒度調整した粉末を作製した。磁粉

(A)のみ使用の圧縮成形ボンド磁石の磁気特性は、*Br*=6.5kG、*iHc*=12.4kOe、 $(BH)_{max}$ =9.0MG0eであった。一方の交換スプリング磁石の組成として、 $Nd_8Fe_{78}Co_7V_2B_5$ なる組成を選び、急冷薄帯を作製した。この薄帯の熱処理後の磁気特性は*Br*=12.1kG、*iHc*=5.0kOe、 $(BH)_{max}$ =19.7MG0eであった。また薄帯の結晶粒径は10~40nm、軟磁性アモルファス相は約7.5面積%、軟磁性結晶相は約60面積%であった。この薄帯を粉碎して、粉体粒度を40μm以下(平均粒径30μm)にふるい、磁粉(B)を作製した。磁粉(B)のみ使用の圧縮成形ボンド磁石の磁気特性は、*Br*=9.3kG、*iHc*=4.6kOe、 $(BH)_{max}$ =11.5MG0eであった。磁粉の混合比を変化させ、前記と同様の方法でボンド磁石を作製し、その磁気特性と磁粉充填率を測定した。その結果を図4に示す。この図4から、充填率は磁粉(B)が40%付近で極大値をとることが分かる。また、本発明の目的とする、*Br*が8kG以上、*iHc*が5kOe以上、 $(BH)_{max}$ が11MG0e以上を満足する磁粉(B)の混合比率は、本実施例の場合は、30~70%の範囲となる。さらに、最高のエネルギー積は40%付近の12.3MG0eであった。

## 【0038】比較例1

実施例1と同じ磁粉の組合せであるが、粉体粒度を同一レベルに、すなわち磁粉(A)と(B)とを共に50~150μmの間に設定し、平均粒径を100μmとして、実施例1と同様にボンド磁石を作製し、磁気特性等を測定した。この場合、磁粉(B)の混合比率10%の減磁曲線から既に目立った変曲点(クニック)が生じはじめ、50%においては、図5に例示するように、最大のクニックを生じ、90%においてもクニックの大きさは減少するものの明かに認められた。また、充填率は混合比率に関わらず79%前後とほぼ一定であり、*iHc*は当然ながら、*Br*も混合比率に比例する平均的な変化を示した。かかる場合、 $(BH)_{max}$ の値は、クニックの存在により算出の意味を有さず、ボンド磁石も実用に供し難いものである。

## 【0039】比較例2

実施例1の磁粉(B)(交換スプリング磁石磁粉)を残存アモルファス相を有しないものに変更、すなわち磁粉(B)を $Nd_4Dy_1Fe_{72.5}Co_3Ga_1B_{18.5}$ なる組成の残存アモルファス相を有しないタイプの $Fe_3B-Nd_2Fe_{14}B$ 型交換スプリング磁石として、熱処理済み急冷薄帯の磁気特性を測定したところ、*Br*=11.9kG、*iHc*=5.0kOe、 $(BH)_{max}$ =1

(7)

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7. 8MG0eであった。磁粉(A)は実施例1と同様に選  
び、磁粉(A)を100~250 $\mu$ m(平均粒径175  
 $\mu$ m)の間に粒度調整し、磁粉(B)を50 $\mu$ m以下  
(平均粒径40 $\mu$ m)に調整した。磁粉(B)が100  
%の単一組成のボンド磁石を作製したところ、Br=  
9.2kGであったが、iHc=1.7k0eと急冷薄帯の  
値に比して大幅に低下し、(BH)max=4.2MG0e  
と低い値となった。一方、磁粉(B)の粒度を100~  
250 $\mu$ m(平均粒径175 $\mu$ m)の間に粒度調整した  
場合の単一組成のボンド磁石は、Br=9.3kG、iH  
c=4.8k0e、(BH)max=10.1MG0eの優れ  
た磁気特性を有するので、磁粉(B)は残存アモルファ  
ス相を有しないため、粉碎粒度が小さくなると、粉碎歪  
みの影響を大きくうけるため、磁気特性が大きく低下す  
るものと考えられる。平均粒径40 $\mu$ mの磁粉(B)を  
用いて、実施例1と同様な方法で磁粉(A)との混合磁  
粉によるボンド磁石を作製し、その磁気特性等を測定し  
たところ、図6に示す如く、磁粉(B)の比率が30%  
付近において充填率の平均値以上への向上と、それに伴  
うBrの向上は見られたが、iHcの低下が大きいた  
め、この点における(BH)maxの値は、平均値的直  
線を越えるものではなく、7.7MG0eと本発明の範囲外  
の低い値であった。

## 【0040】比較例3

実施例2の磁粉(B)(交換スプリング磁石)を残存ア  
モルファス相は有するが、iHcが3.5k0e未満のも

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のに変更し、すなわち磁粉(B)をNd<sub>7</sub>Fe<sub>85</sub>Co<sub>4</sub>  
B<sub>4</sub>なる組成の残存アモルファス相を有する $\alpha$ Fe-N  
d<sub>2</sub>Fe<sub>14</sub>B型交換スプリング磁石として、熱処理済み  
急冷薄帯の磁気特性を測定したところ、Br=12.1  
kG、iHc=3.2k0e、(BH)max=11.9MG  
0eであった。また結晶粒径は10~50nm、軟磁性アモ  
ルファス相は約9.5面積%、軟磁性結晶相は約7.5面  
積%であった。磁粉(A)は実施例2と同様に選  
び、磁粉(A)を100~250 $\mu$ m(平均粒径175 $\mu$ m)  
の間に粒度調整し、磁粉(B)を50 $\mu$ m以下(平均粒  
径35 $\mu$ m)に調整した。磁粉(B)が100%の単一  
組成のボンド磁石を作製したところ、Br=9.7kG、  
iHc=3.0k0e、(BH)max=7.0MG0eであ  
った。実施例2と同様な方法で磁粉(A)と(B)との  
混合磁粉によるボンド磁石を作製し、その磁気特性等を  
測定したところ、図7に示す如く、磁粉(B)の比率が  
40%付近において充填率の平均値以上への向上と、そ  
れに伴うBrの向上は見られたが、混合平均的变化を示  
すiHcの低下が著しく、該40%の点においても(B  
H)maxは9.8MG0eと本発明の範囲外の低い値であ  
った。

【0041】実施例1、2及び比較例1~3に用いた磁  
粉(A)及び(B)の特性を表1に示す。尚、前記した  
実施態様として示した例についても併せて示す。

## 【0042】

【表1】

		実施 態様	実 施 例		比 較 例		
			1	2	1	2	3
磁 粉 (A)	希土類元素含有量(at.%)	11	8.5	9.5	8.5	8.5	9.5
	薄帯のiHc(k0e)	12.9	11.1	12.9	11.1	11.1	12.9
	薄帯のBr(kG)	9.7	8.6	8.4	8.6	8.6	8.4
	薄帯の(BH)max(MG0e)	20.1	15.2	14.7	15.2	15.2	14.7
	平均粉体粒径( $\mu$ m)	150	175	200	100	175	175
磁 粉 (B)	希土類元素含有量(at.%)	7.5	7	8	7	5	7
	薄帯のiHc(k0e)	4.8	4.7	5.0	4.7	5.0	3.2
	薄帯のBr(kG)	11.9	11.6	12.1	11.6	11.9	12.1
	薄帯の(BH)max(MG0e)	18.8	18.6	19.7	18.6	17.8	11.9
	結晶粒径(nm)	10~50	20~60	10~40	20~60	10~60	10~50
	アモルファス相(面積%)	約8	約9	約7.5	約9	0	約9.5
	軟磁性結晶相(面積%)	約60	約65	約60	約65	約70	約75
	平均粉体粒径( $\mu$ m)	50	35	30	100	40	35

(8)

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【0043】

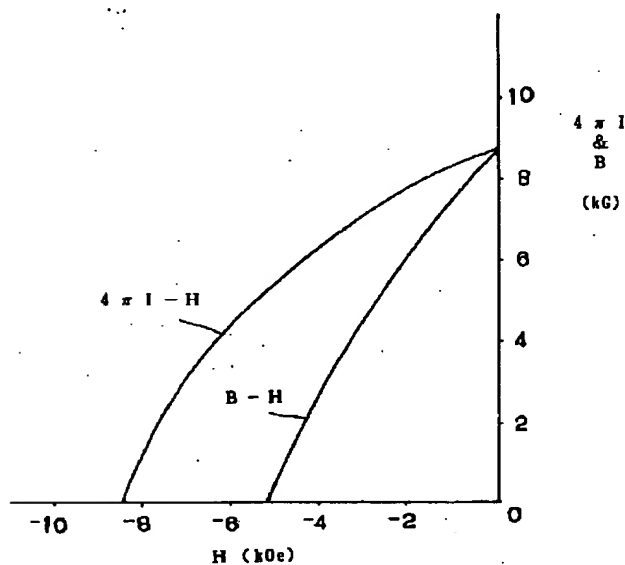
【発明の効果】叙上のとおり、本発明は、特定の磁粉の組合せによる複合効果により、希土類元素が低含有量であるにも拘らず、 $B_r$ が8kG以上、 $iH_c$ が5kOe以上、 $(BH)_{max}$ が11MG0e以上を満足する、高性能Nd系ボンド磁石を経済的に安価に提供するものである。

【図面の簡単な説明】

【図1】実施態様における磁粉(A)/(B)=50/50の場合の希土類ボンド磁石の減磁曲線である。

【図2】実施態様における希土類ボンド磁石の磁気特性

【図1】



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と磁粉充填率を示すグラフである。

【図3】実施例1における希土類ボンド磁石の磁気特性と磁粉充填率を示すグラフである。

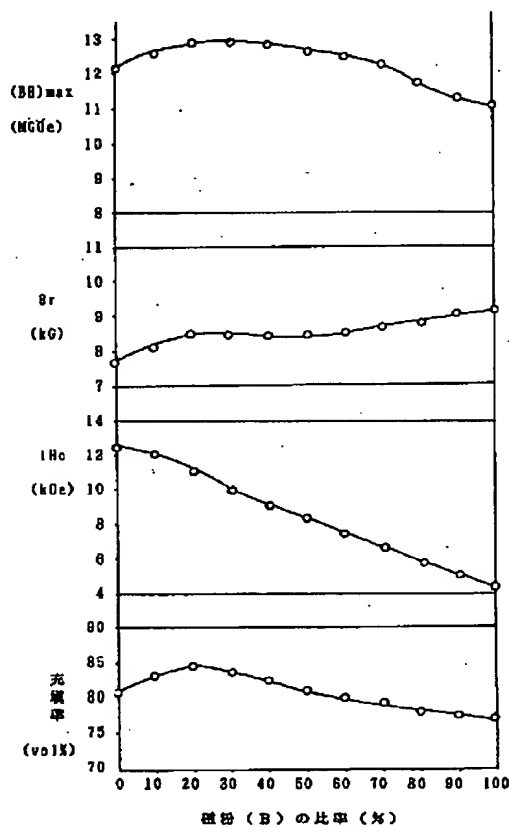
【図4】実施例2における希土類ボンド磁石の磁気特性と磁粉充填率を示すグラフである。

【図5】比較例1における磁粉(A)/(B)=50/50の場合の希土類ボンド磁石の減磁極線である。

【図6】比較例2における希土類ボンド磁石の磁気特性と磁粉充填率を示すグラフである。

【図7】比較例3における希土類ボンド磁石の磁気特性と磁粉充填率を示すグラフである。

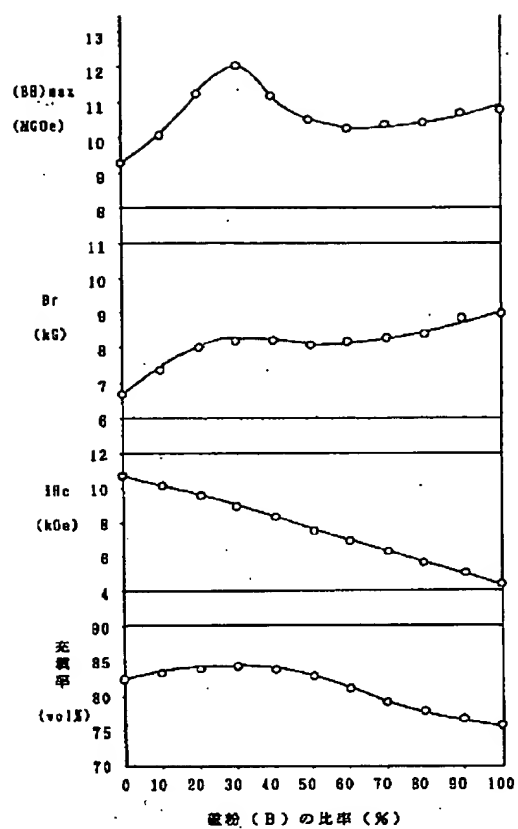
【図2】



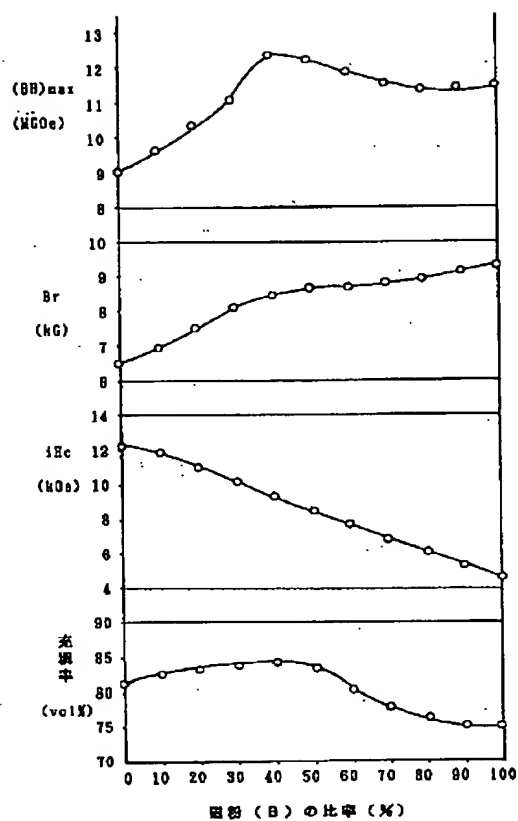


(9)

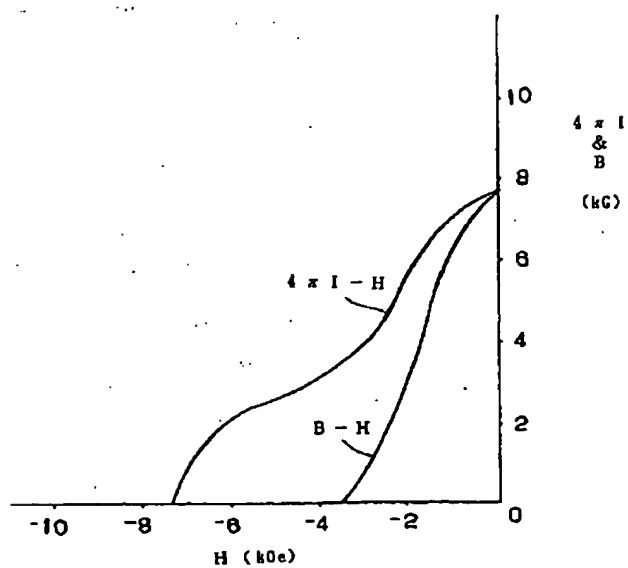
【図3】



【図4】

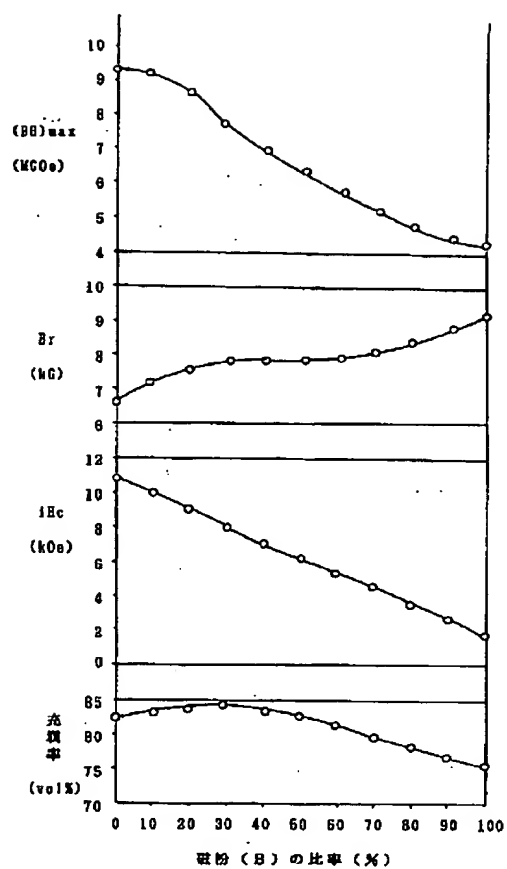


【図5】



(10)

【図6】



【図7】

